Project Number: 95-I7

1996 Annual Report
Regulated Deficit Irrigation for Almond

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Due to increased competition for water from the municipal and environmental sectors, the California almond industry faces the real possibility of limited irrigation water supplies . Whereas traditional irrigation scheduling has the goal of irrigating to fully meet the water use (ETc) of the orchard and to avoid stressing the trees, there simply may not be enough water available to accomplish this in the future. The question then will not be irrigating to prevent tree-water stress, it will be **when** can the orchard be most safely stressed and to what degree (**how much** water should be applied). Moreover, recent research by Goldhamer and Beede (1992) in pistachio, Lampinen et. al. (1994) in prune, Girona et. al. (1993) in peach, and Williams (1993) in grape show that fruit trees and vines can be deprived of water without affecting yield of marketable product.

In 1993, we initiated a project to evaluate regulated deficit irrigation (RDI) on mircrosprinkler-irrigated, shallow rooted trees in the southern San Joaquin Valley. This combination of irrigation method, rooting zone, and location in the state results in rapid development of tree water stress upon deficit irrigation. Our RDI regimes were developed based on previous work suggesting that irrigation can be safely reduced during the 4-6 week period before harvest and about 4 weeks after harvest. Since orchard water use is highest during the preharvest period, potential water savings are greatest at that time.

Based on previous work, we realized that individual kernel weight would be lower when RDI was initiated before mid June following full irrigation. With limited water supplies, emphasizing preharvest irrigation to maximize nut size must be weighed against applying water just before and after harvest to promote successful flower bud development. We feel that the most important yield component in almond production is nut load (# of nuts/tree) which must be maintained if any RDI regime is to be successful. Results from 1995 indicate that some of our RDI regimes have indeed maintained nut loads through the 3 years of this work but individual kernel weight has been sacrificed. We propose to include additional RDI regimes in 1996 designed to maximize kernel size while maintaining fruit load.

Objectives

To test RDI strategies that apply seasonal totals of 22, 28, and 34 acre-inches/acre (deficits of 18, 12, and 6 acre-inches/acre/year, respectively) on cvs. Non Pareil and Carmel in a multiyear field study on shallow rooted, microsprinkler-irrigated trees. The goal of this project is to identify an RDI regime that saves water while not reducing nut yields or quality and thus can be used in normal water availability years.

Material and Methods

Nine deficit irrigation regimes and a fully irrigated control are being evaluated in a large scale (51 acres) field study in Kern Co. Three seasonal irrigation amounts (22, 28, and 34 inches), each applied with 3 different stress timing regimes, are being evaluated in addition to the control that applies 40 inches (Table 1). The "A" treatments impose stress primarily before harvest and emphasize reserving water for postharvest irrigation; the "B" regimes do just the opposite--emphasizing preharvest irrigation with little water left for postharvest. The "C" treatments impose the stress over the entire season. Regardless of the seasonal irrigation amount, care is taken to provide as much water as possible in the 4 week period just before and after harvest. This is to enhance hull split and successful floral bud development, respectively. There are 6 replications of each irrigation regime for a total of 60 plots. Each plot contains 12 each of Non Pareil and Carmel trees. There is one guard tree on the outside of each plot that will receive the same irrigation regime.

Irrigation is with microsprinklers. Each treatment is imposed by engineering the irrigation system to apply different amounts of water while irrigating at the same frequency. This is accomplished by using different combinations of operating pressures and microsprinkler sizes (flow rates). The goal is for each irrigation regime to wet the same surface area. Water meters are used to quantify irrigation amounts.

Results

Individual kernel weight for each of the irrigation regimes for the 3 years of this study is shown in Figure 1. Regardless of the year or the irrigation level, the preharvest stress in the "A" treatments resulted in significantly smaller kernels. When averaged for the 3 experimental years, there was a

18.2, 16.7, and 12.9% reduction in kernel size for the 22A, 28A, and 34A regimes, respectively (Table 2). The "B" treatments also had smaller kernels but to a lesser extent. In most cases, the least impact of the deficit irrigation occurred in the "C" regimes. However, even the "C" treatments had smaller kernels than the Control in the 22 and 28 inch regimes. With 34 inches, there were no statistically significant differences between the "B" and "C" regimes vs. the Control.

After 3 years, there has been relatively little effect of the irrigation regimes on nut load (Figure 2 and Table 2). However, there is a trend developing within each irrigation level; lower nut loads for the "B" treatments. The "A" treatments' nut loads when averaged for 1994-5 were slightly higher than the control, even in the 22 inch regime (Table 2). These trends will be monitored closely in year 4 of this study to identify if the "A" and "B" treatments tend to increase and decrease nut loads, respectively.

Smaller kernel size in the "A" treatments was the primary factor in significantly lower total kernel yields in the 22 inch treatment (Figure 3). When averaged for 1994-5, yields were reduced by 16.8, 23.6, and 9.2% for the "A", "B", and "C" regimes, respectively (Table 2). These are relatively mild responses for a regime that applied 45% less water than the Control. Indeed, yield for 22C was not significantly lower than the Control. Similar non-significant yield reductions occurred in the "C" treatments for the 28 and 34 inch regimes.

For the first 3 years of this study, there have been no statistically significant total kernel yield reductions in all the "C" regimes and 34B. Based on the results of Prichard et al. (1993), an additional study year is needed to make definitive yield conclusions. They found that an RDI regime based on predawn leaf water potential didn't show significant yield reductions until the fourth experimental year. Moreover, continued observation of the existing RDI plots is needed to verify that the "A" regimes can be imposed with no reduction in fruit load. Also, the question remains as to whether 34B and 34C, regimes that save 15% of applied water, will continue to show minimal yield reductions.

RDI regimes to maximize kernel size

Figure 4 shows both dry weight accumulation and predawn leaf water potential for 22A Even though there's significant tree water stress beginning in June, kernel weight isn't affected until early July. Our data show that kernel girth, rather than kernel length, is reduced. We believe that the kernel is a strong sink for photosynthate and has the potential to achieve full size if **severe** tree water stress is prevented in July through harvest. Thus, we propose to test this theory can establishing 3 additional RDI regimes in 1996 (Table 3). These new regimes vary slightly in the duration of deficit irrigation and #2 includes the imposition of mild stress in late July to control hull rot, as per the results of Beth Teviotdale. Since kernel weight is influenced by current season tree water relations (rather than stress history as with nut load), we only need 1 year of dry matter accumulation data with the new plots to verify our theory.

We propose to test 3 additional RDI regimes that are designed to maximize kernel size without reducing fruit load (Table 3). The new plots will be installed on an adjacent field with the same design as the existing plot. The evaluation period will be one year (1996) for the kernel dry matter accumulation. Nut load in 1997 will be determined by gross yield and nut subsample measurements at harvest.

<u>Literature Cited</u>

Girona, J. M. Mata, D. A. Goldhamer, R. S. Johnson, and T. M. DeJong. 1993. Patterns of soil and tree water status and leaf functioning during regulated deficit irrigation scheduling in peach. J. Amer. Soc. Hort. Sci. 118(5):580-586.

Goldhamer, D. A. and R. Beede. 1993. Results of four years of regulated deficit irrigation on deep rooted pistachio trees. Annual Report of the California Pistachio Industry, 1992-93 Crop Year. California Pistachio Commission, Fresno, CA. pp. 107-110.

Lampinen, B., S. M. Southwick, K. A. Shackel, and D. A. Goldhamer. 1994. The effects of water deprivation during different phynological stages of fruit development on prune fruit yields and quality. J. Amer. Soc. Hort. Sci. (submitted).

Prichard, T. L. 1993. Effects of water supply and irrigation strategies on almonds. Proceedings of the 21st Annual Almond Research Conference. Fresno, CA. pp. 29-35.

Williams, L. E. 1993. Irrigation amounts needed to optimize yields of thompson seedless grapevines. Annual Report of the California Table Grape Commission, Fresno CA.

Table 1. Almond regulated deficit irrigation (RDI) treatments.

DATES	CONTROL	34A		34B		34C		28A		28B		28C		22A		22B		22C	
	Normal	RDI	App.	RDI	App.	RDI	App.	RDI	App.	RDI	App.	RDI	App.	RDI	App.	RDI	App.	RDI	App.
	ETc	%	Water	%	Water	%	Water	%	Water	%	Water	%	Water	%	Water	%	Water	%	Water
	(inches)		(inches)		(inches)		(inches)		(inches)		(inches)		(inches)		(inches)		(inches)		(inches)
Mar 1-15	0.5	100	0.5	100	0.5	85	0.5	100	0.5	100	0.5	70	0.4	100	0.5	100	0.5	55	0.3
Mar 16-31	1.1	100	1.1	100	1.1	85	1.0	100	1.1	100	1.1	70	0.8	100	1.1	100	1.1	55	0.6
Apr 1-15	1.4	100	1.4	100	1.4	85	1.2	100	1.4	100	1.4	70	1.0	100	1.4	100	1.4	55	0.8
Apr 16-30	1.8	100	1.8	100	1.8	85	1.5	100	1.8	100	1.8	70	1.2	50	0.9	50	0.9	55	1.0
May 1-15	2.3	100	2.3	100	2.3	85	2.0	50	1.1	100	2.3	70	1.6	50	1.1	50	1.1	55	1.3
May 16-31	3.0	100	3.0	100	3.0	85	2.6	50	1.5	100	3.0	70	2.1	50	1.5	50	1.5	55	1.7
Jun 1-15	3.2	50	1.6	100	3.2	85	2.7	50	1.6	50	1.6	70	2.2	50	1.6	50	1.6	55	1.7
Jun 16-30	3.4	50	1.7	100	3.4	85	2.9	50	1.7	50	1.7	70	2.3	50	1.7	50	1.7	55	1.8
Jul 1-15	3.8	50	1.9	50	1.9	85	3.2	50	1.9	50	1.9	70	2.6	0	0.0	50	1.9	55	2.1
Jul 16-31	3.9	100	3.9	100	3.9	85	3.3	50	2.0	50	2.0	70	2.7	50	2.0	50	2.0	55	2.2
Aug 1-15	3.4	100	3.4	100	3.4	85	2.9	100	3.4	100	3.4	70	2.4	50	1.7	100	3.4	55	1.9
Harvest																			
Aug 16-31	3.3	100	3.3	100	3.3	85	2.8	100	3.3	100	3.3	70	2.3	100	3.3	100	3.3	55	1.8
Sept. 1-15	2.7	100	2.7	100	2.7	85	2.3	100	2.7	100	2.7	70	1.9	100	2.7	50	1.3	55	1.5
Sept. 16-30	2.2	100	2.2	100	2.2	85	1.9	100	2.2	50	1.1	70	1.5	100	2.2	0	0.0	55	1.2
Oct 1-15	1.5	100	1.5	0	0.0	85	1.3	100	1.5	0	0.0	70	1.1	50	0.8	0	0.0	55	0.8
Oct 16-31	1.1	100	1.1	0	0.0	85	1.0	50	0.6	0	0.0	70	0.8	0	0.0	0	0.0	55	0.6
Nov 1-15	0.6	100	0.6	0	0.0	85	0.5	0	0.0	0	0.0	70	0.4	0	0.0	0	0.0	55	0.3
TOTAL (	**39.3**		**34.1**		**34.1**		**33.4**		**28.3**		**27.8**		**27.5**		**22.5**		**21.8**		**21.6**

Summary through 1995

Table 2. Mean values to date of kernel yield and yield components.

Irrigation regime	Full hull split kernel wt. (gms/kernel)*	Fruit load (#/tree)**	Total kernel yield (lbs/acre)**	Scaffold x.s. area growth (cm^2)*
22A	1.08 a	11184 b	1835 ab	19.9 a
22B	1.14 a	9827 a	1685 a	18.3 a
22C	1.14.a	11457 b	2002 bc	17.1 a
28A	1.10 c	11599 c	1932 d	21.6 c
28B	1.19 d	10518 c	1880 d	24.0 c
28C	1.22 d	10856 c	2045 de	22.5 c
34A	1.15 f	11222 d	1964 f	25.9 d
34B	1.24 g	10693 d	2032 fg	24.0 d
34C	1.29 g	11104 d	2177 g	25.0 d
Control	1.32 beg	11054 abcd	2205 ceg	26.9 bcd

* Mean of 1993-1995 (1st-3rd years).

** Mean of 1994-1995 (2nd and 3rd years).

Numbers of the A,B, and C treatments within each irrigation regime and the Control not followed by the same letter are statistically different using Duncan's Multiple Range Test at the 5% confidence level.

Table 3. RDI regimes designed to maximize kernel size to be tested in 1996.

DATES	Days	ETo (in/day)	Kc	CONTROL Normal ETc (inches)	#1 RDI %	#1 App. Water (inches)	#2 * RDI %	#2 * App. Water (inches)	#3 RDI %	#3 App. Water (inches)
Mar 1-15	15	0.09	0.40	0.5	100	0.5	100	0.5	100	0.5
Mar 16-31	16	0.13	0.54	1.1	100	1.1	100	1.1	100	1.1
Apr 1-15	15	0.16	0.60	1.4	100	1.4	100	1.4	100	1.4
Apr 16-30	15	0.18	0.66	1.8	100	1.8	100	1.8	50	0.9
May 1-15	15	0.21	0.73	2.3	50	1.1	50	1.1	50	1.1
May 16-31	16	0.24	0.79	3.0	50	1.5	50	1.5	50	1.5
Jun 1-15	15	0.25	0.84	3.2	50	1.6	50	1.6	50	1.6
Jun 16-30	15	0.26	0.86	3.4	100	3.4	100	3.4	50	1.7
Jul 1-15	15	0.27	0.93	3.8	100	3.8	50	1.9	100	3.8
Jul 16-31	16	0.26	0.94	3.9	100	3.9	100	3.9	100	3.9
Aug 1-15	15	0.24	0.94	3.4	100	3.4	100	3.4	100	3.4
Harvest										
Aug 16-31	16	0.22	0.94	3.3	100	3.3	100	3.3	100	3.3
Sept. 1-15	15	0.19	0.94	2.7	100	2.7	100	2.7	100	2.7
Sept. 16-30	15	0.16	0.91	2.2	100	2.2	100	2.2	100	2.2
Oct 1-15	15	0.12	0.85	1.5	50	0.8	50	0.8	50	0.8
Oct 16-31	16	0.09	0.79	1.1	0	0.0	0	0.0	0	0.0
Nov 1-15	15	0.06	0.70	0.6	0	0.0	0	0.0	0	0.0
Water Use (inches)				**39.3**		**32.5**		**30.6**		**29.9**
Water Saved (inches)						**6.8**		**8.7**		**9.3**
Amount Saved (%)						**17.3**		**22.1**		**23.8**

* Mild stress imposed in early July to minimize hull rot.

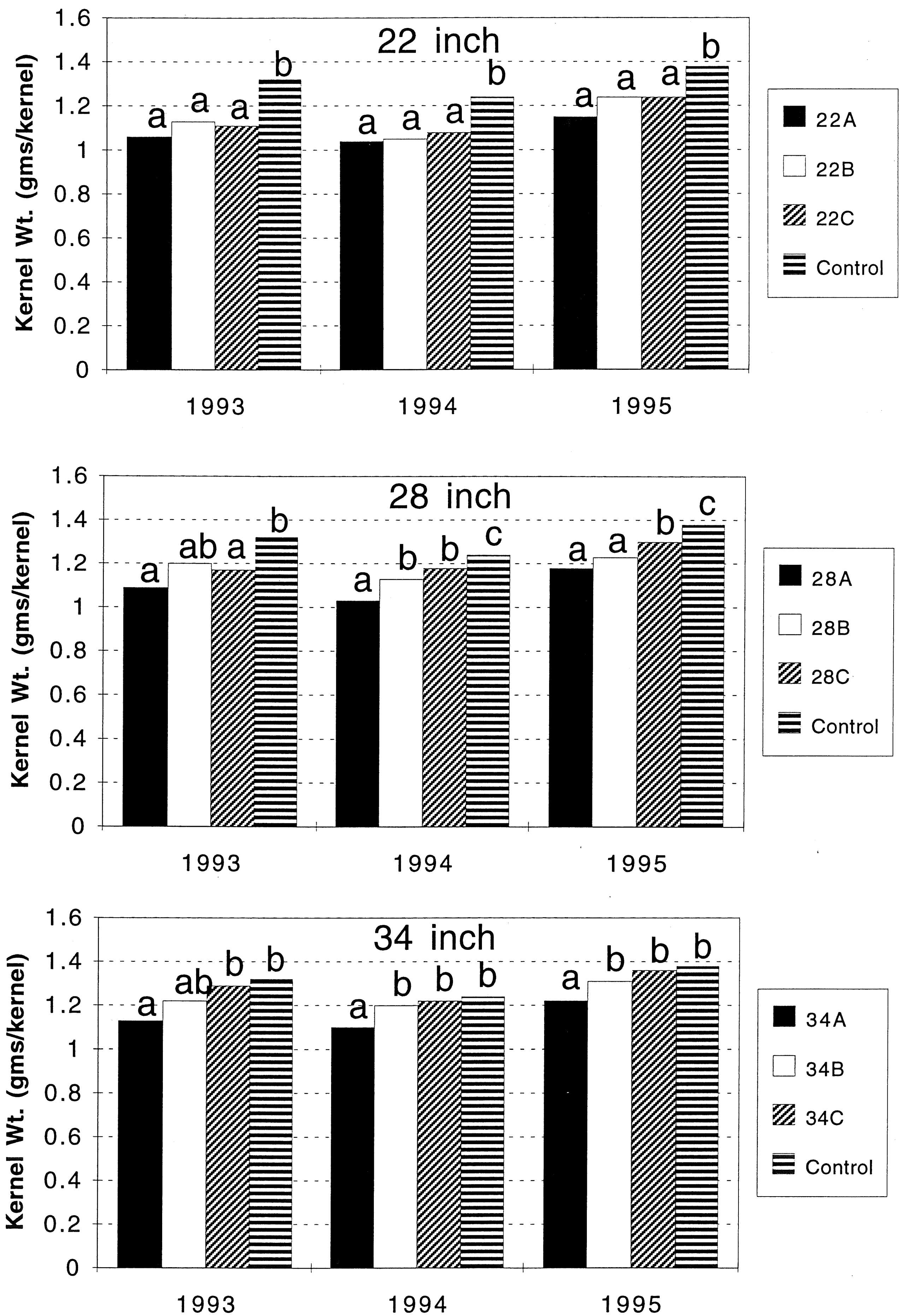

Figure 1. Kernel weight for each experiment year and irrigation level.

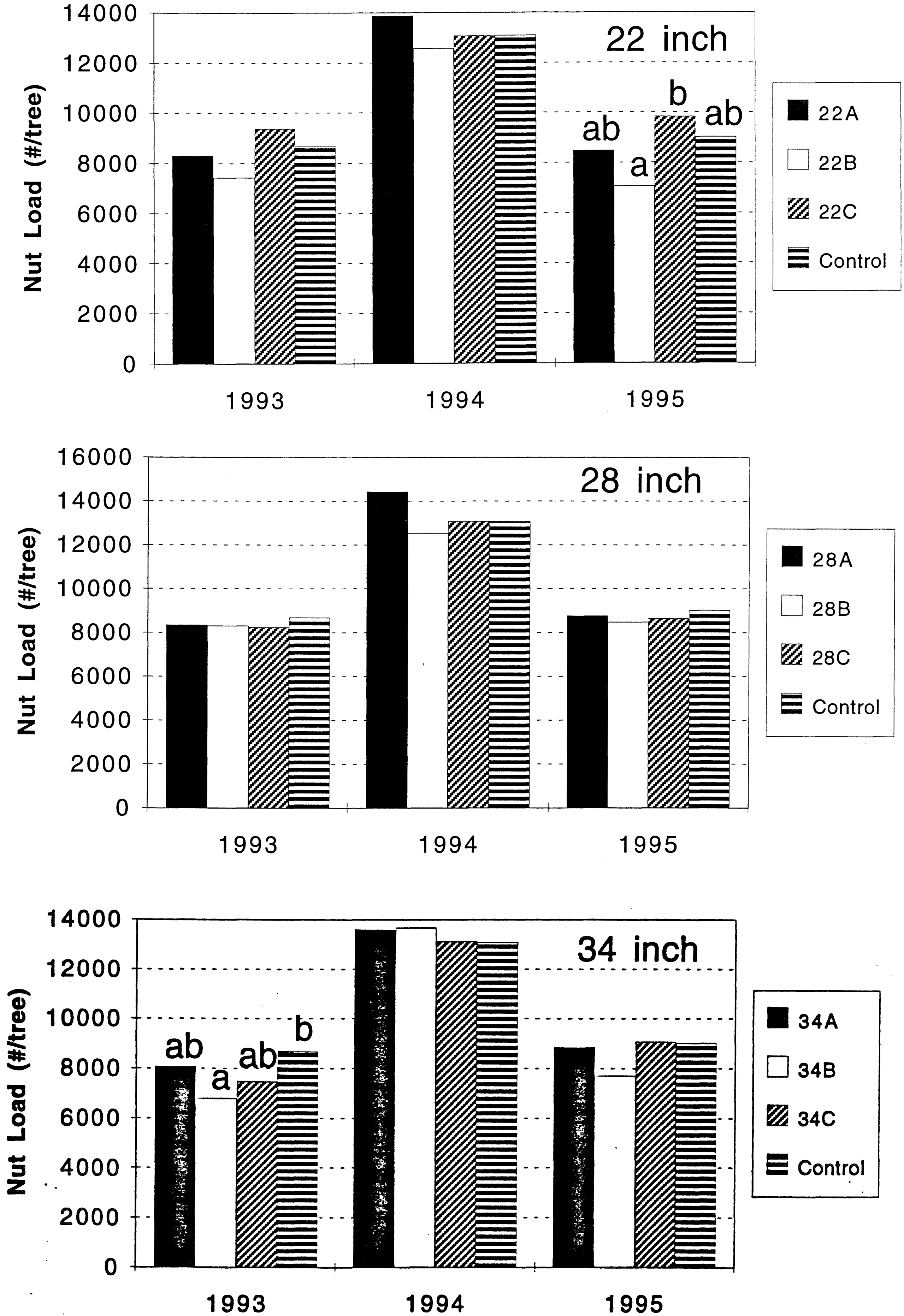

Figure 2. Nut load for each experiment year and irrigation level.

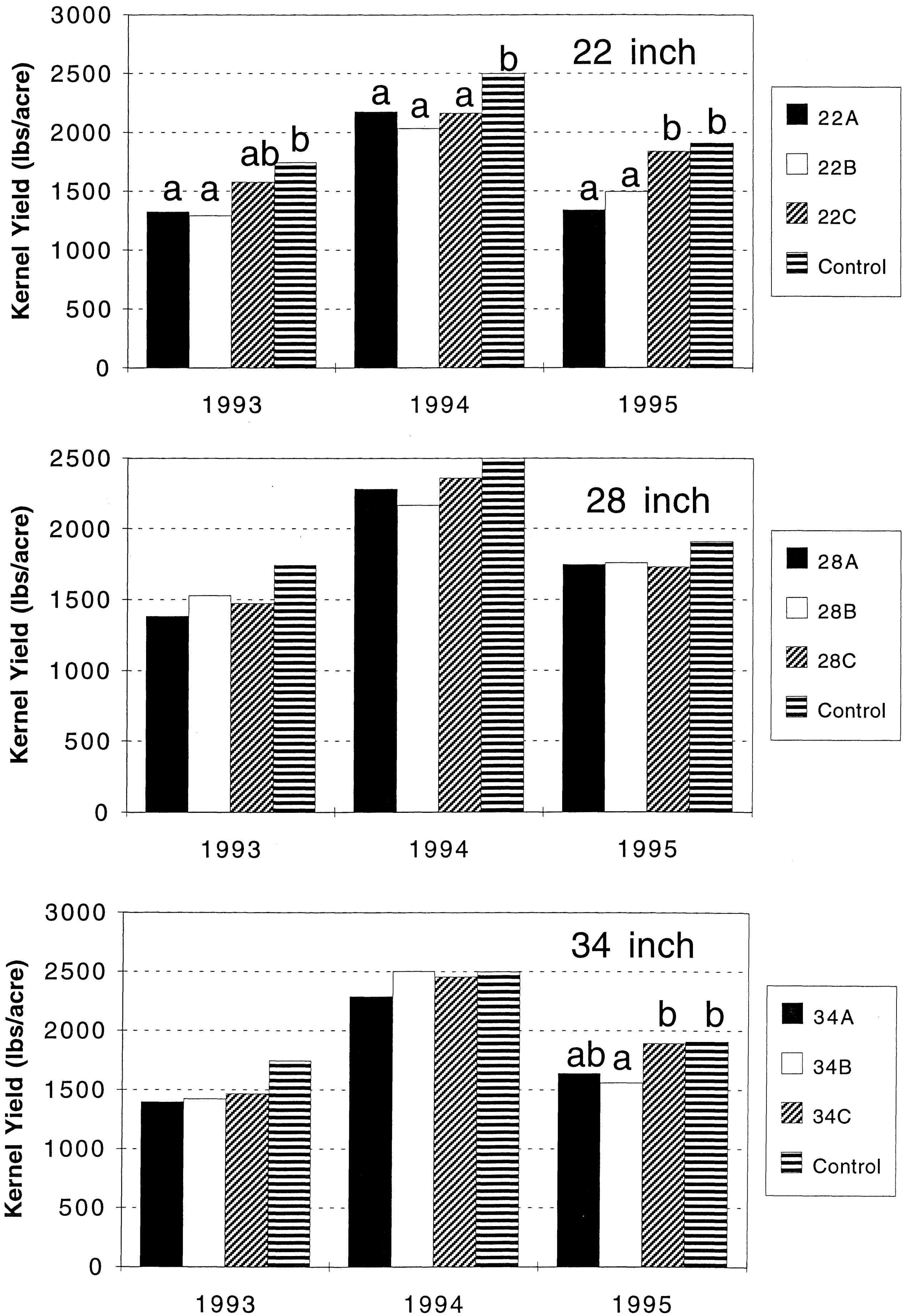

Figure 3. Kernel yield for each experiment year and irrigation level.

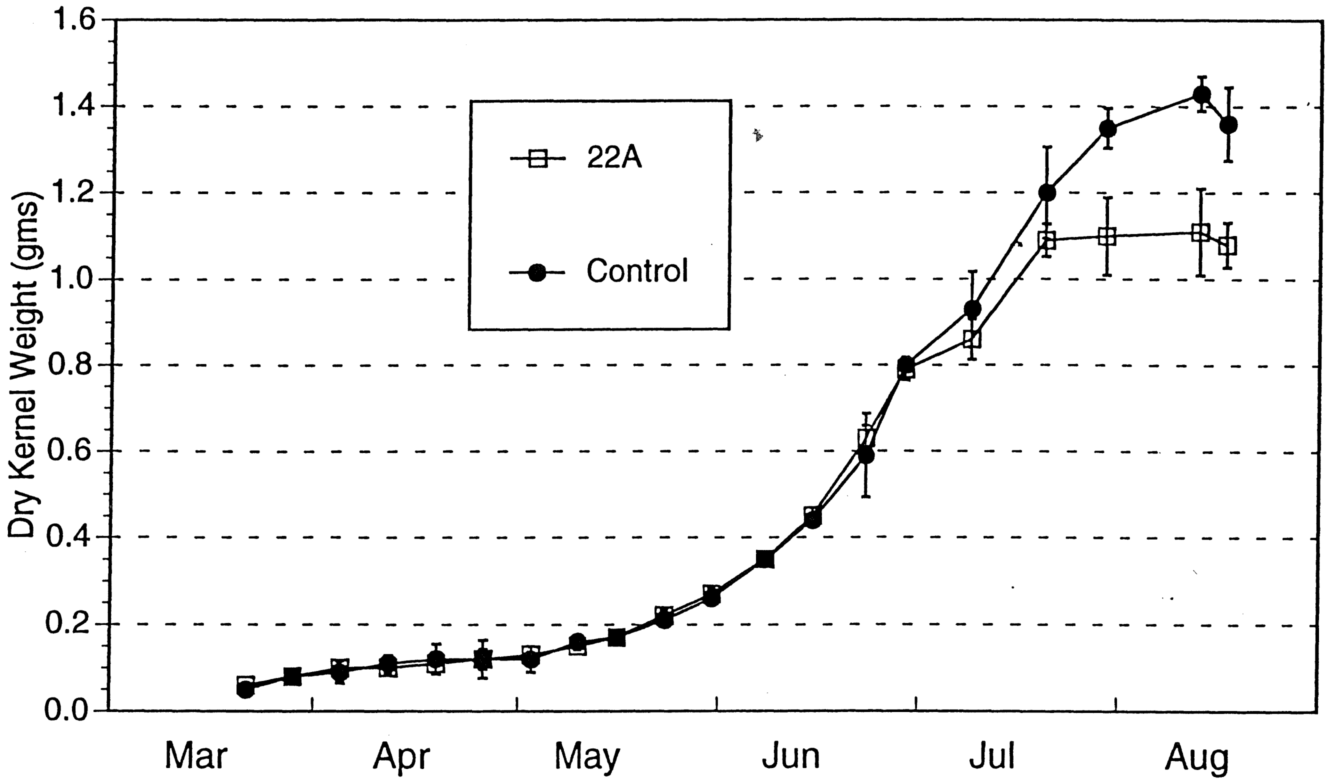

Fig. 4a. 1995 Kernal dry weight with time for 22A. Vertical bars are plus and minus one standard deviation.

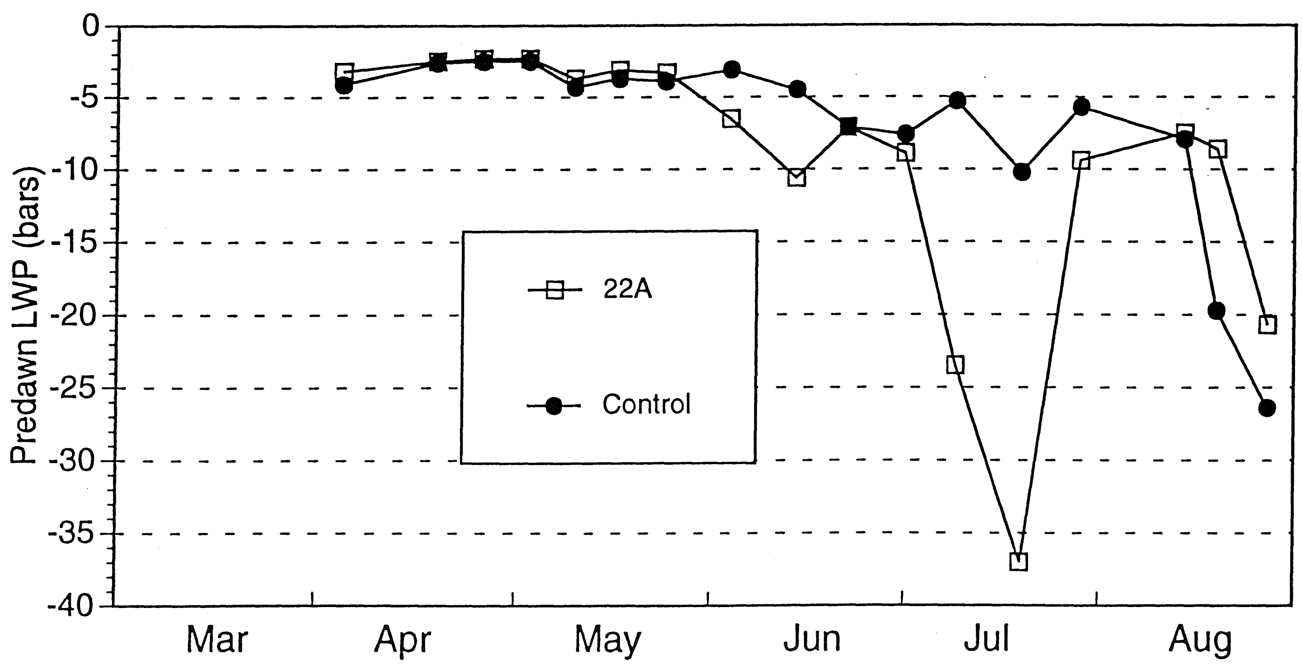

Fig. 4b. 1995 Predawn leaf water potential with time for 22A.

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March 26, 1996

Mr. Joe MacIlvaine
c/o Almond Board of California
1104 12th St.
Modesto, CA 95354

Dear Joe:

Enclosed is my 1995 Annual Report entitled "Regulated Deficit Irrigation of Almond." I appreciate the continued support of the Almond Board for my work.

Sincerely,

Dr. David A. Goldhamer
Water Management Specialist